

LUDLUM MODEL 2224

SCALER/RATEMETER

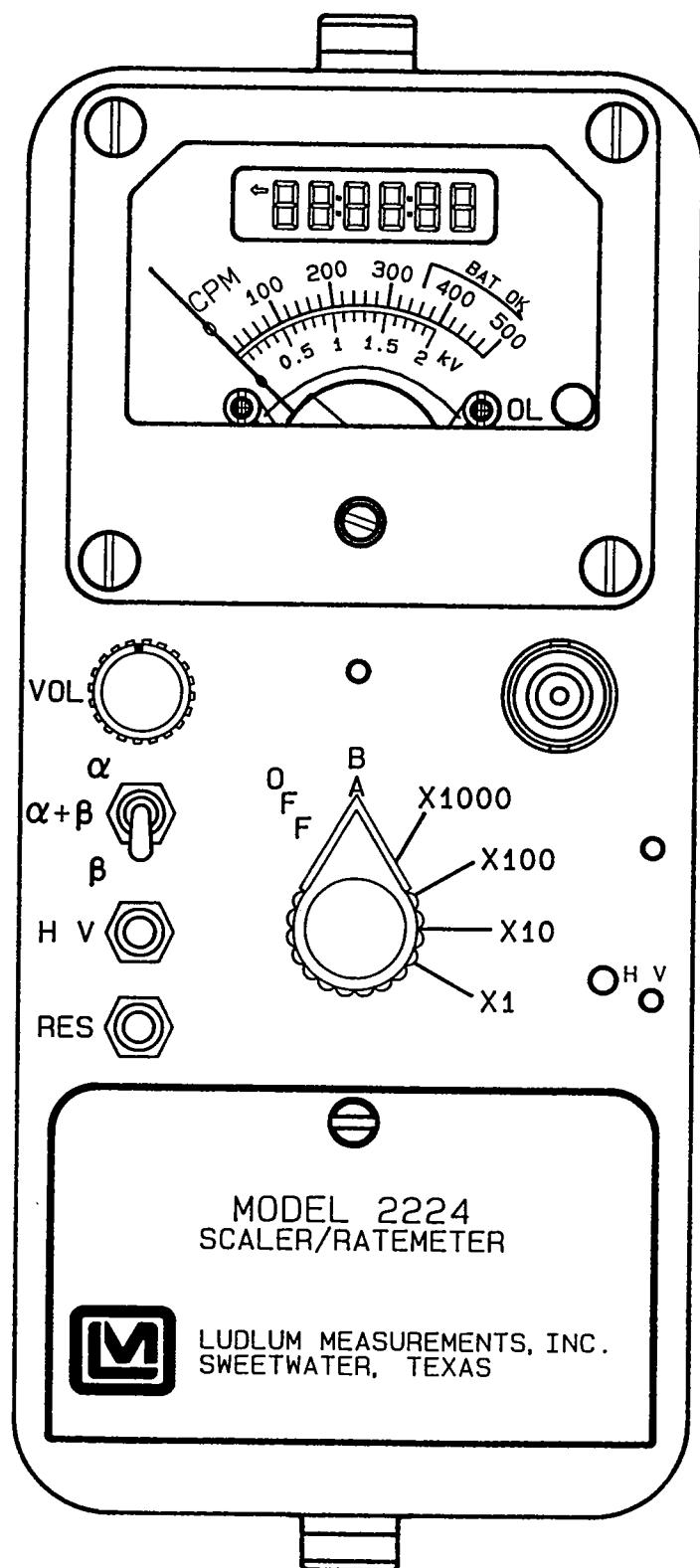
March 2002

**Serial No. 183080 and Succeeding
Serial Numbers**

**Measuring Range: 0-500,000 counts per minute
Power Requirement: two standard "D" cell batteries**



**LUDLUM MEASUREMENTS, INC.
501 OAK ST., P.O. BOX 810
SWEETWATER, TX 79556
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CNS	NO.		DIN	CHK	APP
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TITLE MODEL 2224 SCALER/RATEMETER					
	LUDLUM MEASUREMENTS, INC. 101 DAK STREET SWEETWATER, TEXAS 76088	SERIES 390	SHEET 85		

M2224 Scaler/Ratemeter
March 2002

TABLE OF CONTENTS

1. GENERAL.....	1
2. SPECIFICATIONS.....	1
3. PRINCIPLE OF OPERATION.....	2
4. PRELIMINARY INSTRUCTIONS.....	2
4.1 Unpacking and Repacking	2
5. OPERATING INSTRUCTIONS	2
5.1 Safety Measures	2
5.2 Descriptions of Controls and Functions.....	2
5.2.1 Operator Controls	2
5.2.2 Internal Controls	3
5.3 Operating Procedures.....	4
5.4 Calibration	5
5.4.1 Meter Calibration	5
5.4.2 Detector Overload Calibration	5
6. THEORY OF OPERATION.....	6
6.1 Amplifier/Power Supply board # 5390-066	6
6.1.1 Detector Input/Amplifier.....	6
6.1.2 Alpha/Beta Discriminator	6
6.1.3 Alpha/Beta Disc. Logic Circuit	6
6.1.4 Low Voltage Supply	6
6.1.5 High Voltage Supply.....	6
6.1.6 Detector Overload.....	6
6.1.7 Meter Drive	6
6.2 Processor Bd.# 5390-095	7
6.2.1 Power supply.....	7
6.2.2 Microprocessor	7
6.2.3 LCD Drive	7
6.2.4 Audio.....	7
7. MAINTENANCE	8
 PARTS LIST.....	9
Model 2224 Scaler/Ratemeter.....	9
Amp/Power Supply, Drawing 390 X 63	9
Processor Board, Drawing 390 x 97.....	10
Calibration Board, Drawing 390 x 100.....	10
Display Board, Drawing 390 x 127.....	11
Interconnect Board, Drawing 390 x 124	11
Chassis Wiring Diagram, Drawing 390 X 103.....	11
 DRAWINGS AND DIAGRAMS	12

M2224 Scaler/Ratemeter

March 2002

1. GENERAL

The Model 2224 is a portable microprocessor based radiation survey instrument used to measure and discriminate low level alpha/beta radiation when used with an alpha/beta scintillation or proportional detector.

The data is displayed by an analog ratemeter and a six-digit liquid crystal display (LCD) counter. The ratemeter dial indicates 0-500 CPM with four linear range multipliers of X1-X1000 producing an overall range of 0-500 k CPM. The LCD is used to display the counts accumulated during the preset count time. There are four count times available via internal switches. These count times are 6 seconds, 30 seconds, 60 seconds, and 120 seconds. The counter is reset and started by pressing the Count button located in the end of the carrying handle.

The ratemeter and LCD can display alpha only, beta only, or alpha and beta by selecting the corresponding toggle switch selection. Audible click per event tones can also be selected to discriminate beta (low pitch tone)

from alpha (high pitch tone) via the side mounted speaker. Beta threshold, window, and alpha threshold are adjustable to optimize alpha/beta efficiency and count separation.

A regulated high voltage power supply adjustable from 200 to 2000 volts with detector overload detection is utilized to operate a wide range of scintillation detectors. Other operating features of the instrument include programmable audio divide by (beta channel only), a two-position switch (internal) for selecting the audio discrimination mode, an adjustable volume, pushbutton battery test switch, pushbutton high voltage test switch and meter reset.

The unit body is made of cast aluminum with a drawn aluminum can. The unit is operated with two "D" cell flashlight batteries for operation from -10°C to approximately 50°C. For temperature operation to -10°C, either very fresh alkaline or rechargeable NiCd batteries may be used.

2. SPECIFICATIONS

- **POWER:** two standard "D" size batteries.
- **RANGES:** four linear range multiples of X1, X10, X100, and X1000; used in combination with the 0-500 CPM meter dial, 0-500k CPM is achieved with the range multiplier
- **SENSITIVITY:** beta Threshold (BT) is adjustable from 2 - 15 millivolts (mV), beta Window (BW) is adjustable from the beta Threshold up to the alpha Threshold setting; alpha Threshold (AT) is adjustable from 40 - 700 mV
- **AUDIO:** Dual or single tone click per event through a built-in speaker with an adjustable volume control and internally switchable divide by of 1, 10, 100, and 1000 counts per click (beta only).
- **HIGH VOLTAGE:** externally adjustable from 200 - 2000 volts
- **LINEARITY:** within $\pm 5\%$ of full scale for the analog ratemeter; $\pm 2\%$ for the LCD
- **RESPONSE TIME:** X1 range multiplier = 10 seconds, X10 = 7 sec., X100 = 2 sec., X1000 = 1.5 sec.; all response times measured from 10-90% of full scale
- **BATTERY DEPENDENCE:** Instrument calibration change less than 3% to battery endpoint
- **METER:** 1 mA, 250 degree, 8.3 cm scale, with pivot-and-jewel suspension
- **LCD:** 6 digit Liquid Crystal Display with 6.4 mm characters and a counter overflow arrow, colons indicate count in process
- **CONNECTOR:** Series "C"
- **SIZE:** 10.67 cm (4.2") H x 8.9 cm (3.5") W x 21.6 cm (8.5") L, exclusive of handle
- **WEIGHT:** 1.36kg (3 lbs.) less detector and batteries
- **FINISH:** drawn-and-cast aluminum, with computer-beige polyurethane enamel and silk-screened nomenclature
- **BATTERY LIFE:** Exceeds 350 hours with a fresh set of alkaline "D" cell batteries
- **TEMPERATURE RANGE:** -10°C to 50°C (-14°F to 122°F)
- **CROSSTALK:** No more than 10% of gross alpha counts in beta channel and no more than 1% of gross beta counts in alpha channel.

3. PRINCIPLE OF OPERATION

The Model 2224 is to be used in combination with alpha/beta scintillation or proportional detectors. The M2224 uses pulse heights discrimination to distinguish between alpha and beta pulses from the radiation detector.

The detected alpha count is displayed by selecting the α position on the three position α , $\alpha + \beta$, and β toggle switch. The sum of the alpha and beta counts are displayed in the $\alpha + \beta$ position and beta counts are displayed in the β position. Multiply the cpm reading on the analog ratemeter by the range multiplier position. When using the LCD and preset count time interval, the counts are accumulated in each of the three channels during the count cycle. The alpha, alpha + beta, and

beta counts can be displayed by selecting the appropriate α , $\alpha + \beta$, β channel. The count cycle is started by depressing the pushbutton switch located in the end of the carrying handle.

The RESET pushbutton switch resets the meter pointer to zero. The detector operating voltage is displayed on the meter dial, 0-2 kV (kilovolts), by depressing the HV switch. The OL (overload) lamp, located at the lower right-hand corner of the meter dial, is to indicate that the detector is saturated either by a puncture in the detector face on a scintillation detector or an exposure to a radiation field above the counting capability of the M2224. The analog meter will deflect full scale when the OL lamp is illuminated.

4. PRELIMINARY INSTRUCTIONS

4.1 Unpacking and Repacking

- Remove calibration certificate and place in secure location. Remove instrument and accessories (batteries, cable, etc.) and ensure that all of the items listed on the packing list are in the carton. If more than one instrument (M2224 and detector) is in carton refer to the calibration certificate for serial number match.

- To return instrument for repair or calibration provide sufficient packing material to prevent damage during shipment. Provide appropriate warning labels to ensure careful handling. Include detector(s) and related cable(s) for calibration. Include brief information as to the reason for return and return shipping instructions (address, P.O.#, etc.).

5. OPERATING INSTRUCTIONS

5.1 Safety Measures

CAUTION

The high voltage (HV) constant current output is limited by the internal circuitry to approximately 50 microamps, but a mild electric shock may occur if you make contact with the input connector. Switch the M2224 to the OFF position before connecting or disconnecting the cable or detector.

Multiply the scale reading by the multiplier for determining the actual reading.

During the initial turn ON, the meter will be driven full scale for about 2 seconds and then return to zero. The LCD will show "888888", display the processor program version, and then 0.

5.2 Descriptions of Controls and Functions

5.2.1 Operator Controls

- **OFF/BAT/X1000/X100/X10/X1 Switch:** A six position rotary switch to select the analog meter range multipliers and check the battery status. When switched to the BAT position the meter pointer should deflect above the left vertical mark on the BAT OK line. Moving the range selector switch to one of the range multiplier positions (X1, X10, X100, X1000) provides the operator with an overall range of 0-500 k cpm.

- **Liquid Crystal Display (LCD):** 6 digit display that displays the scaler count for the selected channel. The display also indicates when a count is in progress by turning on two colons. The colons are turned off when the count is completed. If the counter exceeds 999999, an arrow in the upper left corner of the display turns on to indicate the overflow and the counter rolls over to zero and continues counting.

- **VOL:** The volume control for the speaker. Turning this control clockwise will increase the speaker volume and counterclockwise will decrease the volume.

✓NOTE: The volume should be turned down when not required to reduce battery drain.

M2224 Scaler/Ratemeter

March 2002

- **$\alpha/\alpha+\beta/\beta$ Switch:** A three-position toggle switch used to select the sum of both alpha and beta count channels ($\alpha+\beta$), alpha count only (α), or beta count only (β), for display. This switch affects both the ratemeter and the counter. The separate ratemeter and counter channels are active regardless of the switch position and will continue to function when the channel is not selected for display. This allows the operator to view each channel separately or together by simply selecting the appropriate switch position.

- **HV:** When depressed, provides a readout of the detector high voltage on the meter. Use the 0-2 kV meter scale.

- **RESET:** When depressed, provides a rapid means to drive the analog ratemeter to zero.

- **Count Pushbutton Switch (located in carrying handle):** When depressed, resets the counter to zero and starts the timer. The colons on the display will turn on and stay on until the count time has expired.

- Remove the CAL cover to access the following control.

- **HV Adjustment:** Provides a means to vary the high voltage from 200 to 2000 volts.

5.2.2 Internal Controls

- Remove the instrument cover (can) to access the following controls.

- **AUDIO Divide Select Switch:** A two-pole DIP switch (1 & 2) used to select the audio divide ratios of 1, 10, 100, 1000.

✓ NOTE: The AUDIO divide function only effects the lower frequency beta tones. The higher frequency alpha clicks per events will be unaffected by the divide by selection.

The ratio is selected from the following table. O is open and C is closed.

SWITCH	DIVIDE BY
1 2	RATIO
C C	1
O C	10
C O	100
O O	1000

- **COUNT TIME Select Switch:** A two-pole DIP switch (3 & 4) used to select the count times of 6, 30, 60, and 120 seconds.

The count time is selected from the following table. O is open and C is closed.

SWITCH	COUNT TIME
3 4	
C C	6 seconds
O C	30 seconds
C O	60 seconds
O O	120 seconds

- **TONE:** A one-pole DIP switch (5) used to select tone discrimination between alpha and beta count channels. When in the DUAL mode, alpha and beta pulse tones will be audible in all selector switch positions (i.e. if in the α only position and β is detected, the β tones will be heard in addition to the α tones and visa versa).

When the SNGL tone position is selected, both alpha and beta pulse tones can be heard in the $\alpha+\beta$ selection, but alpha pulses cannot be heard in the beta only channel selection and beta pulse tones will not be heard in the alpha only channel selection.

SWITCH	TONE
5	MODE
C	DUAL
O	SINGLE

✓ NOTE: The following controls are utilized during calibration only and should only be performed by a qualified calibrator.

- **MTR:** A multi-turn potentiometer used to calibrate the meter to the cpm reading.

- **AT:** A multi-turn potentiometer used to vary the alpha pulse threshold from \approx 40 to 700 mV.

- **BW:** A multi-turn potentiometer used to vary the beta pulse upper window limit from the beta threshold to the alpha threshold setting and anywhere in between those two parameters. The beta window can be disabled by adjusting the BW control to the maximum clockwise position allowing the upper beta threshold limit to equal the alpha threshold.

- **BT:** A multi-turn potentiometer used to vary the beta pulse threshold from \approx 2 to 15 millivolts.

- **OL:** A multi-turn potentiometer which provides a means to vary the detector current overload set point.

- **LIM:** A multi-turn potentiometer used to set the maximum HV limit to 2000 VDC.

M2224 Scaler/Ratemeter

March 2002

- **HV:** A multi-turn potentiometer used to adjust the high voltage test reading to correspond with the actual high voltage output. The HV switch must be depressed during adjustment.
- **LB:** A multi-turn potentiometer used to adjust the minimum battery voltage level corresponding to the low battery indication on the meter dial. The BAT switch must be depressed during adjustment.

5.3 Operating Procedures

- Release the can latches and remove the can from the 2224 taking care not to damage the speaker wires. Using a ball point pen, set the switches for the AUDIO divide by, TONE, and COUNT TIME to the desired selection. Then replace the can and fasten the latches.
- ✓ NOTE: To open the Battery Lid, twist the lid button counterclockwise 1/4 turn. To close, twist clockwise 1/4 turn.
 - Open the Battery Lid and install two "D" size batteries. Note (+) (-) marks on the inside of the lid. Match the battery polarity to these marks.
 - ✓ NOTE: Center post of flashlight battery is positive. Close the battery box lid.
 - Connect a detector to the M2224.
 - Switch the OFF/BAT/X1000-X1 switch to the BAT position. The meter pointer should deflect above the left vertical mark on the BAT OK line. If the meter does not respond correctly, recheck that the batteries have proper polarity and are good. The LCD should show all eights, display the program version number, and then display 0.
 - The detector operating parameters are established by adjusting the detector operating voltage (HV), alpha threshold, and beta window to find an optimum efficiency for the alpha/beta scintillator or proportional detector.
- The threshold and window parameters can be adjusted to optimize alpha/beta count discrimination, count efficiency, and minimize "cross talk" between channels. Refer to the specific detector Operation Manual or calibration certificate for the suggested threshold and window settings. Once the thresholds and window settings are established, an operating voltage versus count rate plot should be performed for both alpha and beta count channels with alpha and beta particle emission sources.
- The following procedure is example of determining the operating voltage for an alpha/beta scintillation or proportional detector:
 - Connect a Ludlum Model 500 Pulser or equivalent to the Model 2224.
 - Switch the 2224 to the β position. Adjust the beta threshold (BT) for 3.5 mV and the window (BW) for 30 mV. The pulser counts should be detected on the 2224 ratemeter above 3.5 ± 1 mV and should shut off above 30mV.
 - Switch the channel selector switch to the α position. Adjust the pulser for a 120mV pulse output and vary the AT control until counts are detected on the ratemeter.
 - Depress the HV switch and adjust the HV potentiometer for 0.4 to 0.5 kV on the 0-2.0 kV scale. Connect the scintillator and switch to the β only position. Place an alpha source on the detector face.
 - Slowly increase the HV potentiometer to observe an increase, then decrease, and increase again in count as the HV is increased. Decrease the HV until the ratemeter is in the "dip" of the observed count rate versus HV plot just performed. Depress the HV switch and note the HV setting.
 - Plot a HV versus count rate plateau in 25 volt increments, 50 volts each side of the HV reading found in the above step (ie, HV setting for count "dip" in the above step = 675 volts, start the plot at 625 volts and increase in 25 volts steps until 725 volts is reached). Plot alpha source, beta source, and background counts for both the α and β channel positions.
 - Find the optimum operating voltage from the plot which gives the greatest alpha and beta source efficiency while maintaining no greater than the maximum acceptable level of "cross talk" between channels.
 - Select the desired count channel display, and proceed to use instrument.

M2224 Scaler/Ratemeter

March 2002

5.4 Calibration

5.4.1 Meter Calibration

- A Ludlum Model 500 Pulser or equivalent is required. If the Pulser does not have a high voltage readout, use a high impedance voltmeter with at least 1000 Megohm input resistance to measure the detector voltage.

- Ensure that the meter movement has proper mechanical zero. The adjustment is on the front of the meter bezel. It must be adjusted to "zero" with the ON/OFF selector switch in the OFF position.

- Connect the Model 500 Pulser to the Model 2224 with the appropriate cable. Rotate the M2224 range multiplier switch to the X100 position. Select the $\alpha + \beta$ channel position.

- Adjust the Pulser for 40,000 cpm and adjust the pulse amplitude to twice the beta threshold level (ie; beta threshold = 3.5mV, adjust pulser to 7-10mV).

- Remove the instrument cover and adjust the MTR potentiometer until the meter reads 400 cpm. Adjust the Pulser to 10,000 cpm and ensure ratemeter reads $100 \pm 10\%$. Decade the Pulser and M2224 range multiplier switch to check meter linearity on the X1000, X10, X1 positions. Linearity should be within $\pm 10\%$ of each reading.

- Set the LCD count time for 60 seconds. Adjust Pulser count rate to 40k cpm. Depress the count button and when count cycle is complete confirm that LCD reads within $\pm 2\%$ of the incoming count rate.

- Adjust the BT, BW, and AT controls for the appropriate set points as described in section 5.3.

- Connect high impedance high voltage meter (may use the Model 500 Pulser if equipped with a HV meter) and adjust the HV control for a reading of 1000 VDC on the voltmeter.

- Depress the HV pushbutton switch and adjust the HV potentiometer located on the circuit board for a reading of 1.0 kV on the meter dial. Adjust the HV output from 500 to 1500 Vdc and confirm that the 2224 HV meter corresponds to the external voltmeter within $\pm 10\%$ of each reading.

- Remove batteries from the battery compartment and connect a DC power supply to the two screw terminals located at the rear of the battery compartment. The positive power supply lead should connect to the terminal with the red wire and the negative lead to the terminal with the black wire.

- Adjust the power supply for 2.2 Vdc and switch the M2224 to the $\alpha + \beta$ position. Depress the BAT pushbutton switch and adjust the LB potentiometer to align the meter needle with the low battery mark on the meter dial (vertical line to the left of BAT OK).

- Replace M2224 cover and proceed with use.

5.4.2 Detector Overload Calibration

✓ NOTE: The detector operating voltage (HV) must be determined and set before the OL (overload) adjustment is performed. If the detector operating voltage is re-adjusted, the overload adjustment must be re-adjusted.

- Adjust the OL control to the maximum counterclockwise position.

✓ NOTE: Detector saturation is when the meter response no longer increases with increasing radiation field intensity.

- For alpha/beta scintillators, expose the detector photomultiplier tube (PMT) to a small light leak by loosening the detector window. Some scintillation detectors incorporate a screw in the detector body which when removed will simulate a detector face puncture or light leak. The meter should start to decrease toward zero as light saturates the scintillation material.

- Expose just enough light to where the meter starts to decrease. Adjust the OL control until the overload LED just begins to flicker on the meter dial. The ratemeter should deflect above full meter scale at this point.

- Re-seal the detector window and expose the detector to a radiation source that will drive the meter near full scale. Confirm that the LED does not turn on and the meter remains on scale.

6. THEORY OF OPERATION

6.1 Amplifier/Power Supply board # 5390-066

Refer to schematic 390 x 63 for the following:

6.1.1 Detector Input/Amplifier

Negative going detector pulses are coupled from the detector through C021 to Amplifier U021. R023 and CR021 protects the input of U021 from inadvertent shorts. Self-biased amplifier U021 provides gain in proportion to R021 divided by R022. Transistor pins 4, 5, and 6 of U021, provides amplification. Pins 12 and 15 of U021 are coupled as a constant current source to pin 6 of U021. The output self-bias to 2V be (approximately 1.4 volts) at pin 7 of U021. This provides just enough bias current through pin 6 of U021 to conduct all of the current for the constant current source. Positive pulses from pin 7 of U021 are coupled to the discriminators through R011 and C011.

6.1.2 Alpha/Beta Discriminator

Positive pulses from amplifier U021 are coupled to comparator U012, pin 6, for alpha discrimination and pins 6 and 2 of U011 for beta discrimination. R103, Alpha Threshold, provides the reference voltage for alpha comparator U012. R106, Beta Threshold (defined as the lower threshold limit of the beta counting window) provides the reference voltage for beta threshold comparator pins 1, 2, and 3 of U011. R102, Beta Window (defined as the upper threshold limit of the beta counting window) provides the reference voltage for the beta window comparator pins 5, 6, and 7 of U011.

6.1.3 Alpha/Beta Disc. Logic Circuit

Alpha pulses from U012 are coupled to univibrator U111. Pulses at pin 6 of U111 are inverted by Q111 for connection to reset (R) pins 3 and 13 of U101. Pin 9 of U111 provides the pulses to be counted the microprocessor (μ P). Pulses from pin 9 of U111 are connected to pin 3 of U111 to provide a time delay for the μ P clock cycle to complete before the next alpha pulse can be recognized by the μ P.

Beta pulses from pin 1 of U011 are coupled to univibrator U101. Pulses are coupled to the μ P from pin 7 of U101 as long as pins 3 and 13 of U011 remain high (+5V). When an alpha and/or a beta window pulse is present, the reset (pins 3 and 13 of U101) function is enabled and 7 of U101 remains high. Pin 7 of Up is connected to pin 13 of U101 to provide a time delay for

the μ P clock cycle to complete before the next beta pulse can be recognized by the μ P.

6.1.4 Low Voltage Supply

Battery Voltage is coupled to switching regulator U201 and associated components to provide +5V to power op-amps and logic circuitry. The charge pump (cp) output, C202, CR211, CR212, and C201 form a voltage doubler circuit to provide +9V for U201 amplifier supply. U001 and related components provide +2.5V reference HV SET and Alpha/Beta discriminator controls. R201, LO BAT, is adjusted so that the meter pointer is aligned with the left vertical mark on the BAT OK line with 2.2 volt battery input.

6.1.5 High Voltage Supply

High Voltage is developed blocking oscillator Q421, T321, C412, and rectified by voltage multiplier CR221-CR224, C221-C223, C211, and C114. High voltage increases as current through Q421 increases, with maximum output voltage with Q421 saturated.

High voltage is coupled back through R123 to op-amp pin 2 of U311. Resistor network R211-214 completes the HV division circuit to ground. R214 provides HV limit at 2.0 kV when the HV SET control on the calibration board is at maximum. The regulated HV output is controlled by HV potentiometer located under the CAL cover on the front panel. This control provides the reference for comparator pin 3, U311. During stable operation, the voltage at pin 2 of U311 will equal the voltage at pin 3 of U311. Pin 1 of U311 will cause conduction of Q312 to increase or decrease until the HV finds a level of stability. R115, HV TEST, calibrates the analog meter to the HV output when the HV test pushbutton switch is depressed.

6.1.6 Detector Overload

A voltage drop is developed across R121 and sensed by comparator U012 as detector current increases. When the voltage at pin 3 of U012 goes below pin 2, pin 1 goes low illuminating the OL LED and driving the meter to full scale. R211, Overload, provides adjustment for the overload set point.

6.1.7 Meter Drive

Pulses are coupled from the μ P board (refer to μ P theory of operation) to the gate of Q302. Q302 inverts the pulses, R403 and C401 provides integration. Integrated meter drive voltage is coupled from P1-13 via

M2224 Scaler/Ratemeter

March 2002

the battery (BAT) and HV test switch to pin 5 of U311. The meter is driven by the emitter of Q111, coupled as a voltage follower in conjunction with pin 6 and 7 of U311. R104, Meter Cal, is adjusted to calibrate the ratemeter reading corresponding to the incoming count rate. R405 and R406 provide temperature compensation for changes in the meter resistance due to temperature variations.

6.2 Processor Bd.# 5390-095

Refer to schematic 390 x 97 for the following:

6.2.1 Power supply

Battery voltage is coupled to switching regulator U201 and associated components to provide +5V to power the μ P and display drivers U211, 212. R101, C101, Q101, and Q201 form a delay switch which allow the U321 to stabilize before the load current is connected to the +5V supply.

6.2.2 Microprocessor (μ P)

U311, Intel N87C51FA, controls all of the data, control inputs, and display information. The clock frequency is crystal controlled by Y211 and related components at 6.144 MHz. The μ P incorporates internal memory (ROM) storing the program information. C311 resets the μ P at power-up to initiate the start of the program routine. During the program

loop the μ P looks at all of the input switches for initiation or status changes and responds accordingly.

The μ P uses Pulse-width Modulation to control the analog ratemeter. The analog output, RATE (P3-4), is divided into 255 increments in a 166 μ s period. At full meter deflection the low pulse period, leading edge to leading edge, will be 166 μ s, 500 cpm = 130 μ s, 400 cpm = 104 μ s, 200 cpm = 52 μ s, 100 cpm = 26 μ s, and 0 = no pulse or +5V. The pulses are inverted by Q302 on the Amplifier/Power Supply board and then integrated by R403, C401.

6.2.3 LCD Drive

U211 and U212 make up the liquid crystal display drive circuitry. The display information is sent from the μ P to U211 and 212 via BUS0-3 and ADD0-1 data lines. When the SELECT' line is brought low by the μ P, the data is transferred and latched into the drivers until the SELECT' line is brought low again. The corresponding digits and segments are illuminated corresponding to the stored count information from the μ P.

6.2.4 Audio

Alpha and/or beta audio pulse frequency is generated by the μ P and coupled to Q204. Q204 then inverts the pulses and drives the negative side of the speaker. Bias voltage is provided by the volume control via Q202 and 203 and related circuitry.

M2224 Scaler/Ratemeter
March 2002

7. MAINTENANCE

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration.

An instrument operational check should be performed prior to each use by exposing the detector to a known source and confirming the proper reading on each scale.

Re-calibration should be accomplished after any maintenance or adjustment of any kind has been performed on the instrument. Battery replacements are not considered to be maintenance and do not normally require the instrument to be recalibrated.

Ludlum Measurements recommends recalibration at intervals no greater than one year. Check the appropriate regulatory agencies regulations to determine required recalibration intervals.

The batteries should be removed and the battery contacts cleaned of any corrosion at least every three months. If the instrument has been exposed to a very dusty or corrosive atmosphere, more frequent battery servicing should be used.

Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removing the handle will facilitate access to these contacts.



NOTE

NEVER STORE THE INSTRUMENT OVER 30 DAYS WITHOUT REMOVING BATTERIES.
ALTHOUGH THIS INSTRUMENT WILL OPERATE AT VERY HIGH AMBIENT TEMPERATURES,
BATTERY SEAL FAILURE CAN OCCUR AT TEMPERATURES AS LOW AS 100° FAHRENHEIT.

M2224 Scaler/Ratemeter
March 2002

PARTS LIST

Ref. No.	Description	Part No.	Ref. No.	Description	Part No.
Model 2224 Scaler/Ratemeter					
UNIT	Completely Assembled Model 2224 Scaler/Ratemeter	48-2494	U021	CA3096M	06-6288
			U101	CD74HC4538M	06-6297
			U111	CD74HC4538M	06-6297
			U201	MAX631AESA	06-6285
			U311	TLC27M7ID	06-6292
Amp/Power Supply, Drawing 390 X 63					
• DIODES					
BOARD	Completely Assembled Amp/PS Board	5390-066	CR021	MMBD7000LT1	07-6355
			CR111-112	MMBD914L	07-6353
			CR211-CR212	BAT54	07-6354
			CR221-CR225	GI250-2	07-6266
			CR411	MMBD914L	07-6353
• CAPACITORS					
C001	100pF, 100V	04-5661	R001	22.1k, 1%	12-7843
C002	47pF, 100V	04-5560	R002	249k, 1%	12-7862
C011	0.1μF, 50V	04-5663	R003	22.1k, 1%	12-7843
C012-C014	0.001μF, 100V	04-5659	R004	1.5k, 1%	12-7878
C015	0.1μF, 50V	04-5663	R011	100 OHM, 1%	12-7840
C016	0.01μF, 50V	04-5664	R013	22.1k, 1%	12-7843
C017	10μF, 20V	04-5655	R014	33.2k, 1%	12-7842
C021	100pF, 3kV	04-5532	R015	10k, 1%	12-7839
C022	10pF, 100V	04-5673	R016	22.1k, 1%	12-7843
C101-C102	47pF, 100V	04-5560	R017	10k, 1%	12-7839
C111-C113	47pF, 100V	04-5560	R021	392k, 1%	12-7841
C114	0.0047μF, 3kV	04-5547	R022-R023	10k, 1%	12-7839
C121-C122	0.0047μF, 3kV	04-5547	R024	33.2k, 1%	12-7842
C201-C202	10μF, 20V	04-5655	R025	22.1k, 1%	12-7843
C203	330pF, 100V	04-5657	R026	1 MEG	10-7028
C211	0.0047μF, 3kV	04-5547	R101	100k, 1%	12-7834
C212	68μF, 6.3V	04-5654	R102-R103	1 MEG TRIMMER	09-6906
C213	1μF, 35V	04-5656	R104	22.1k, 1%	12-7843
C214	0.01μF, 50V	04-5664	R105	100k, 1%	12-7834
C221-C223	0.0047μF, 3kV	04-5547	R106	10k TRIMMER	09-6921
C301	68μF, 6.3V	04-5654	R111	100 OHM 1%	12-7840
C311	0.1μF, 50V	04-5664	R112	1G	12-7686
C401	0.1μF, 50V	04-5663	R113-R114	100k, 1%	12-7834
C411	0.1μF, 50V	04-5663	R115	1 MEG TRIMMER	09-6906
C412	1μF, 35V	04-5656	R116	249k, 1%	12-7862
C421	68μF, 6.3V	04-5654	R121	4.7 MEG	10-7030
• TRANSISTORS					
Q111	2N7002L	05-5840	R122	1 MEG	10-7028
Q301	MMBT4403LT	05-5842	R123	1G	12-7686
Q302	2N7002L	05-5840	R201	200k TRIMMER	09-6908
Q311-C312	MMBT3904T	05-5841	R211	1 MEG TRIMMER	09-6906
Q421	MJD210	05-5843	R212-R213	1 MEG, 1%	12-7844
• INTEGRATED CIRCUITS					
U001	LM285M-2.5	06-6291	R214	1 MEG TRIMMER	09-6906
U011-U012	TLC372ID	06-6290	R215	1 MEG, 1%	12-7844
			R301	2.21k, 1%	12-7835
			R302	200 OHM, 1%	12-7846
			R311	10k, 1%	12-7839

M2224 Scaler/Ratemeter
March 2002

R312	22.1k, 1%	12-7843	• INTEGRATED CIRCUITS		
R313	2.21k, 1%	12-7835			
R314	10k, 1%	12-7839	U211-U212		
R401	221k, 1%	12-7845	ICM7211AMIQH		
R402	7.5k, 1%	12-7847	U311		
R403	1M, 1%	12-7844	N87C51FA		
R404	5k TRIMMER	09-6907	U321		
R406	301 OHM, 1%	12-7863	MAX631AES		
R407	1k, 1%	12-7832	• RESISTORS		
R411	200 OHM, 1%	12-7846	R101	1M, 1%	12-7844
R412	10k, 1%	12-7839	R102	10k, 1%	12-7839
• THERMISTORS			R211	2.21k, 1%	12-7835
R405	03006-165.9-55G100	07-6366	R221	150k, 1%	12-7833
• INDUCTORS			R222	100k, 1%	12-7834
L301	220μH	21-9678	R301-R306		
• TRANSFORMERS			• RESISTOR NETWORK		
T321	L8050	40-0902	RN401	220k	12-7831
• MISCELLANEOUS			• CRYSTALS		
P1	CONN-1-640456-5		Y211	6.144 MHZ	01-5262
P2	MTA100	13-8355	• SWITCHES		
*	CONN-640456-3		L311	150μH	21-9677
*	MTA100	13-8081	• MISCELLANEOUS		
*	M2222 BD. SHIELD	7390-044	S301	90HBW06S	08-6710
	RECEPTACLE (8 ea)		• INDUCTOR		
	Cloverleaf 011-6809	18-8771	P3	CONN-1-640456-6	
Processor Board, Drawing 390 x 97			P4	MTA100	13-8134
BOARD	Assembled Processor	5390-095	*	CONN-640456-2	
• CAPACITORS				MTA100	13-8073
C101	0.15μF, 50V	04-5665		SOCKET-44P	06-6293
C110	47μF, 10V	04-5666	Calibration Board, Drawing 390 x 100		
C211-C212	27pF, 100V	04-5658	BOARD	Completely Assembled	
C221	68μF, 6.3V	04-5654		Calibration Board	5390-096
C311-312	10μF, 20V	04-5655	• LEDs		
C321	330pF, 100V	04-5657	DS1	HLMP4700	07-6356
C322	68μF, 6.3V	04-5654		LED-SPACER 456-500	07-6349
• TRANSISTORS			• RESISTORS		
Q101	2N7002L	05-5840	R3	250k TRIMMER	09-6819
Q201	MMBT4403L	05-5842	• MISCELLANEOUS		
Q204	2N7002L	05-5840			
Q311	MMBT4403L	05-5842			
• MISCELLANEOUS			P7	CONN-640456-5	
				MTA100	13-8057

M2224 Scaler/Ratemeter
March 2002

Display Board, Drawing 390 x 127

BOARD	Completely Assembled Display Board	5390-118
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• CONNECTORS

DSPI	LCD 7728-365-481	07-6351
J6	CONN-52 POS CP50	13-8410

Interconnect Board, Drawing 390 x 124

BOARD	Completely Assembled Interconnect Board	5390-117
J5	• CONNECTORS CONN-52 POS CP50	13-8410

Chassis Wiring Diagram, Drawing 390 X 103

• AUDIO

DS1	UNIMORPH	21-9251
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• CONNECTOR

J1	CONN-1-640442-5 MTA100	13-8383
J2	CONN-640442-3 MTA100	13-8135
J3	CONN-1-640442-6 MTA100	13-8187
J4	CONN-640442-2 MTA100	13-8178
J7	CONN-640442-5 MTA100	13-8140
J8	Series "C" UG706/U	13-7751

• SWITCHES

S1	PA-600-210	08-6501
S2	#923 SWTCHCRFT	08-6518
S4	30-1-PB GRAYHILL	08-6517
S5	7103SYZQE TOGGLE	08-6720

• BATTERY

B1-B2	"D" Duracell Battery	21-9313
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• MISCELLANEOUS

J10	JACK-09-9011-1-0419	18-9080
M1	METER ASSY	4390-136
*	HANDLE ASSY	4408-075

M2224 Scaler/Ratemeter
March 2002

DRAWINGS AND DIAGRAMS

Amp/Power Board, Drawing 390 x 63

Amp/Power Supply Board Component Layout, Drawing 390 x 64

Processor Board, Drawing 390 x 97

Processor Board Component Layout, Drawing 390 x 98

Calibration Board, Drawing 390 x 100

Calibration Board Component Layout, Drawing 390 x 101

Display Board, Drawing 390 x 127

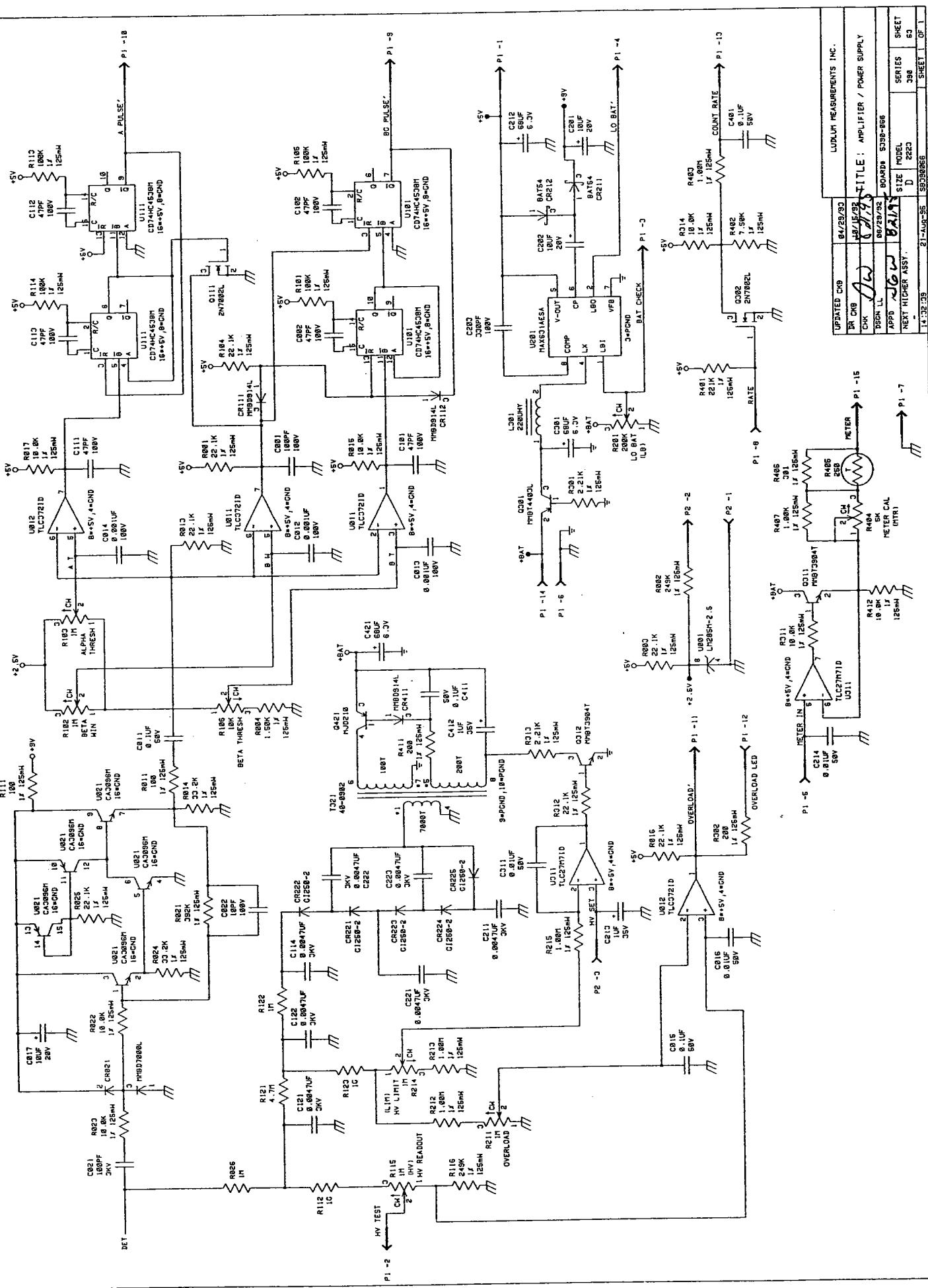
Display Board Component Layout, 2 sheets, Drawing 390 x 128

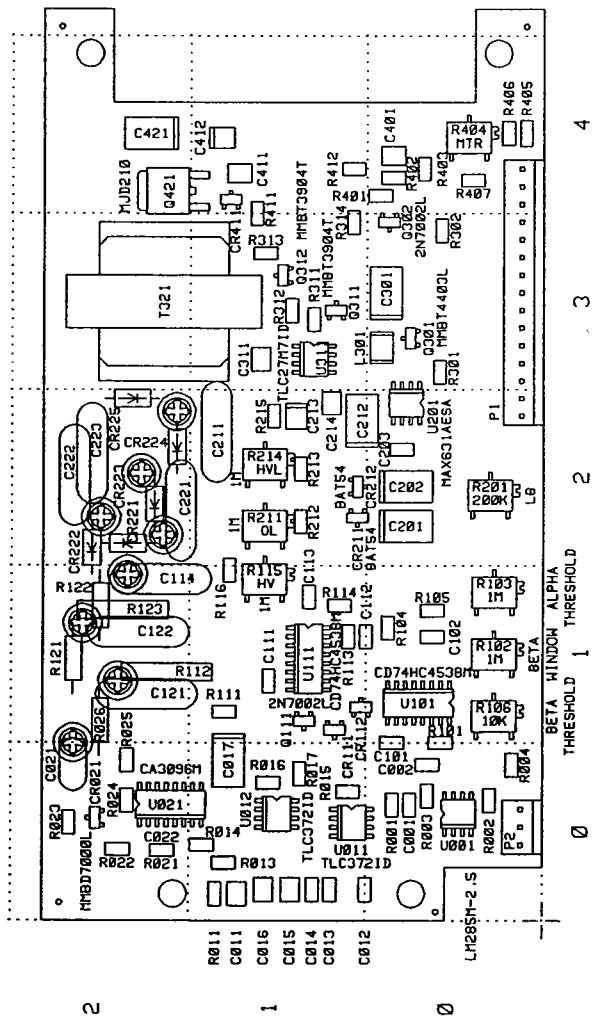
Interconnect Board, Drawing 390 x 124

Interconnect Board Component Layout, Drawing 390 x 125

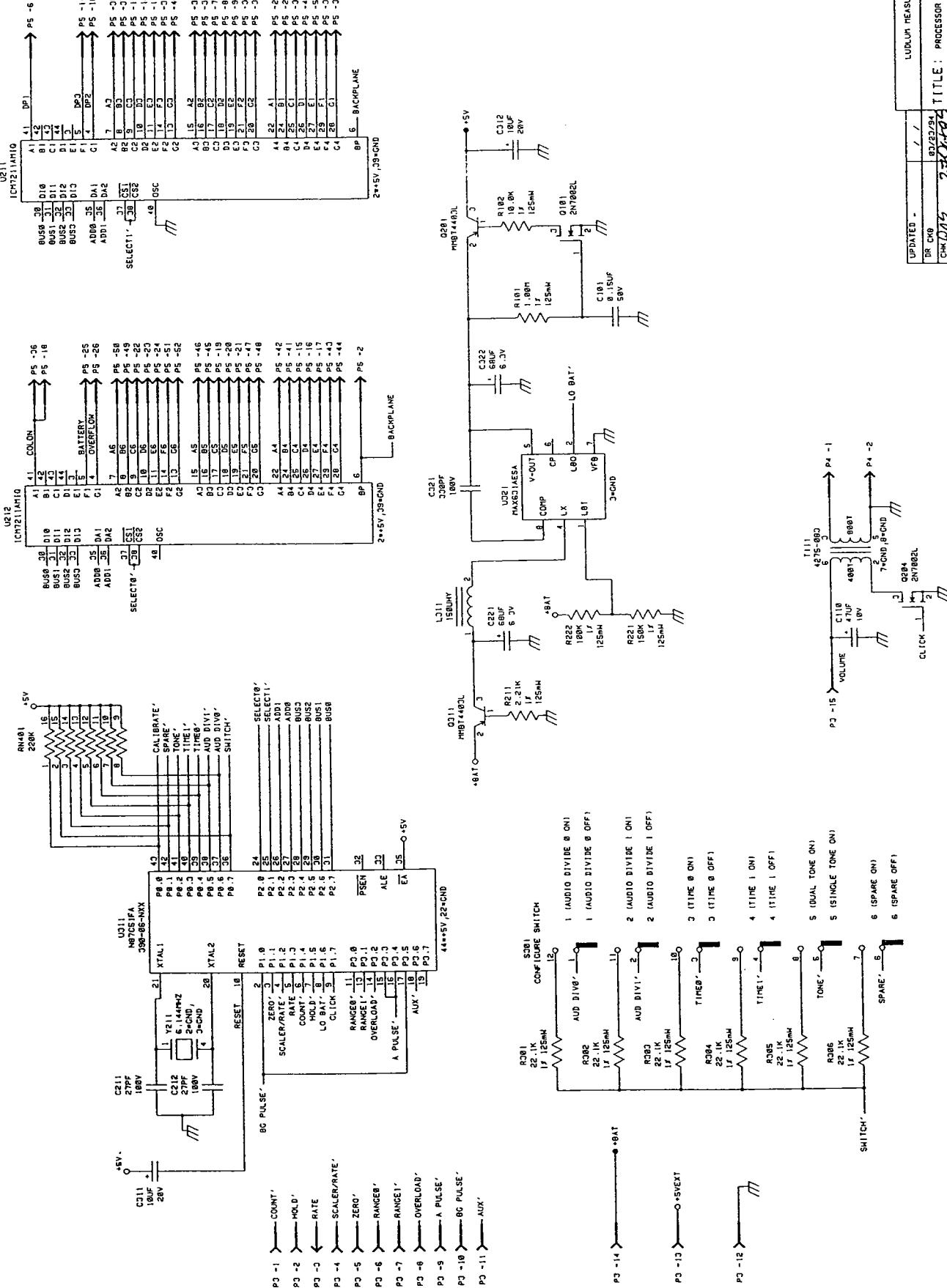
Wiring Diagram, Drawing 390 x 103

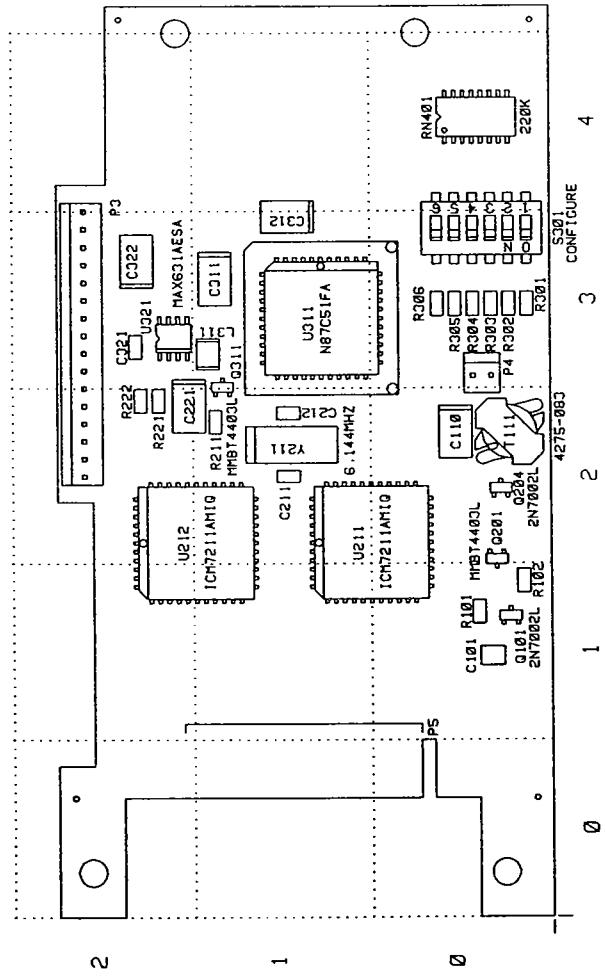
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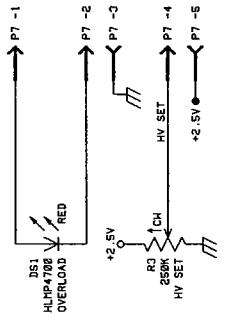
LUDLUM MEASUREMENTS INC. SHEETWATER, TX.
 DRB CIR 04-29-93 TITLE : AMPLIFIER /
 CLK DLM 04-19-93 BOARD : POWER SUPPLY
 DSGN LL 05-29-92 MODULE : 5390-066
 APP DLM 04-22-93 SERIES : 5390-066
 APP DLM 04-22-93 SHEET : 56
 APP DLM 04-27-93 COMP SLDR : OUTLINE &
 COMP PASTE O CONP MASK : SLDR PASTE O SLDR MASK O



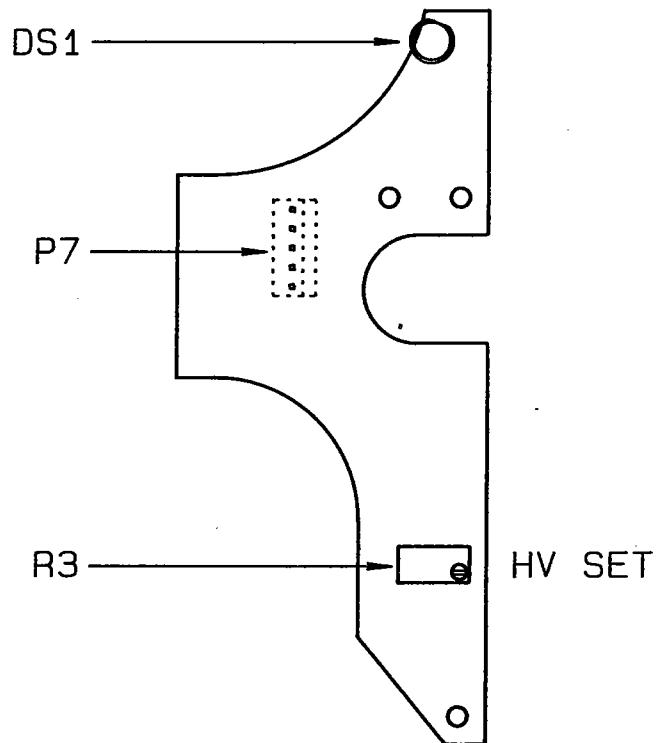


LUDLUM MEASUREMENTS INC. SHEETWATER, TX.
 DR. CIR. 83-22/94 TITLE: PROCESSOR BOARD
 CHK 105 32662 BOARD: W.O. E.L.
 DSCN LL 6/12/91 MODEL: 5390-095 SER. # BS3590095
 APP VLSI 102/91 2224 S/N: 190 SWEET 98
 T/S: 46 27-OCT-95 COMP SIDE SDR SIDE OUTLINE
 COMP PASTE SDR COMP MASK SDR PASTE SDR MASK
 SDR

REF	AUTHORITY	ZONE	LTR	REVISIONS	DATE	APPROVED
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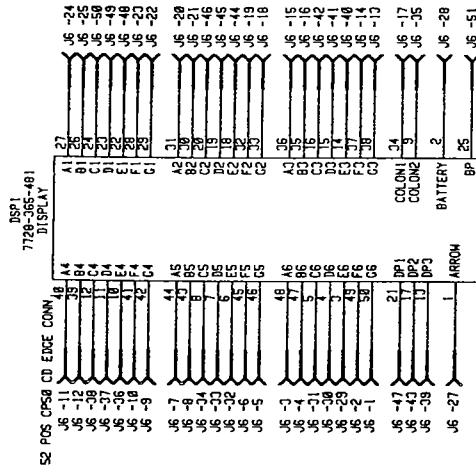


UPDATED -	/ /	LUDUM MEASUREMENTS INC.
DR CIR	84/21/84	TITLE : CALIBRATION BOARD
CHK <i>ROS</i>	84/21/84	DESIGN LL
BOARD	5395-956	96/12/91
APPD <i>View</i>	10293	SIZE D
NEXT HIGHER ASSY.		MODEL 2224
-		SERIES 398
18153-88	27-Oct-95	SHEET 1 OF 1
	39392956	



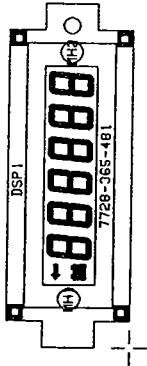
DESC: CALIBRATION BOARD	
MODEL: 2224	
PART #: 5390-096	
DWN: CKB	DATE: 04/01/94
DSGN:	DATE:

REF NO.	DATE	WORK DATE	DATE
04/01/94	270495	10/1/94	
TITLE	SCALE	REMARKS	INSTRUMENT
TITLE MODEL 2224 CALIBRATION BOARD		390 101	
100%	100%	100%	100%

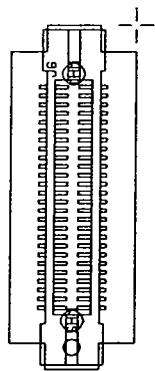


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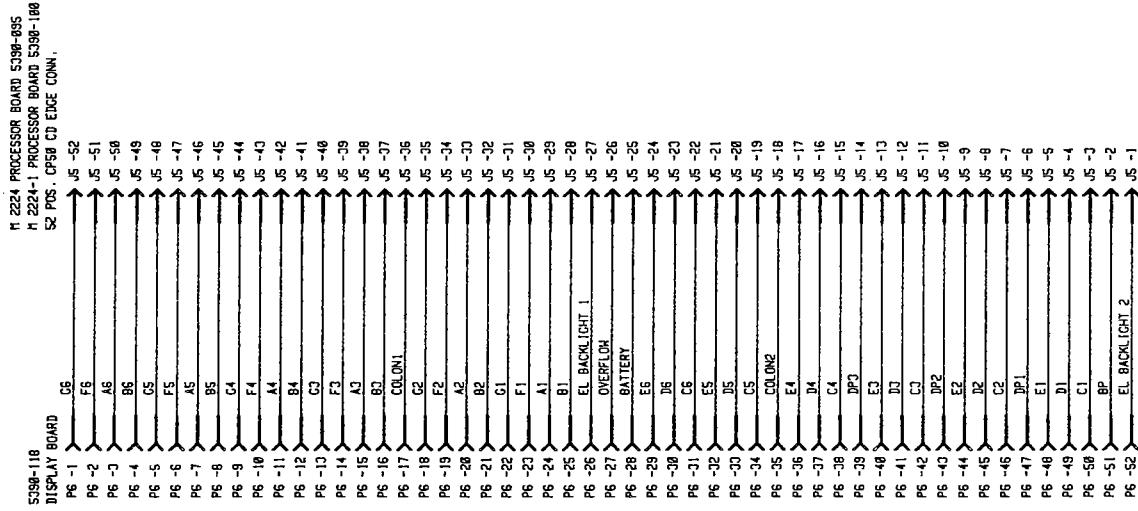
		LUDUM MEASUREMENTS INC., SHEETWATER, TX.	
DR	ACF	02-JUN-98	TITLE: DISPLAY BOARD
CHK	JCH	6-2-98	BOARD: 5590-18
DESIGN	JCH	17-JUL-98	MODEL: 2224
APP	Z-2-299		FILENAME: 85399118
COMPONENT	SOLDER	10-21-98	2-Jun-99
OUTLINE	OUTLINE	REVISION	SERIES
		1	0
		390	128



<input checked="" type="checkbox"/>	LUDLUM MEASUREMENTS INC.	SHEETWATER , TX.
DR	ACF	92-JUN-93
CHK	P/J/J	2 - 2 - 97
DSGN	JCH	MODEL 2224
APP	BS	17-JUL-95
CORP PASTE	<input type="checkbox"/>	COMP MASK
CORP PASTE	<input type="checkbox"/>	SLDR PASTE
CORP OUTLINE	<input type="checkbox"/>	SLDR OUTLINE
CORP ARTWORK	<input type="checkbox"/>	SLDR ARTWORK
BOARD	5390-118	SHEET 1 128
TITLE :	DISPLAY BOARD	

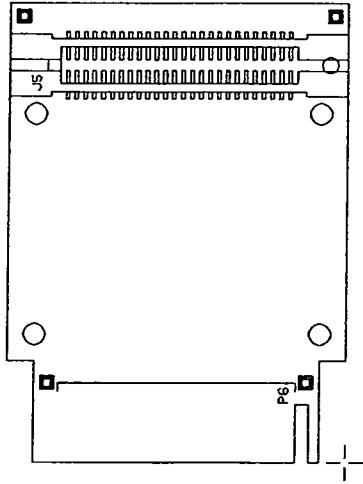


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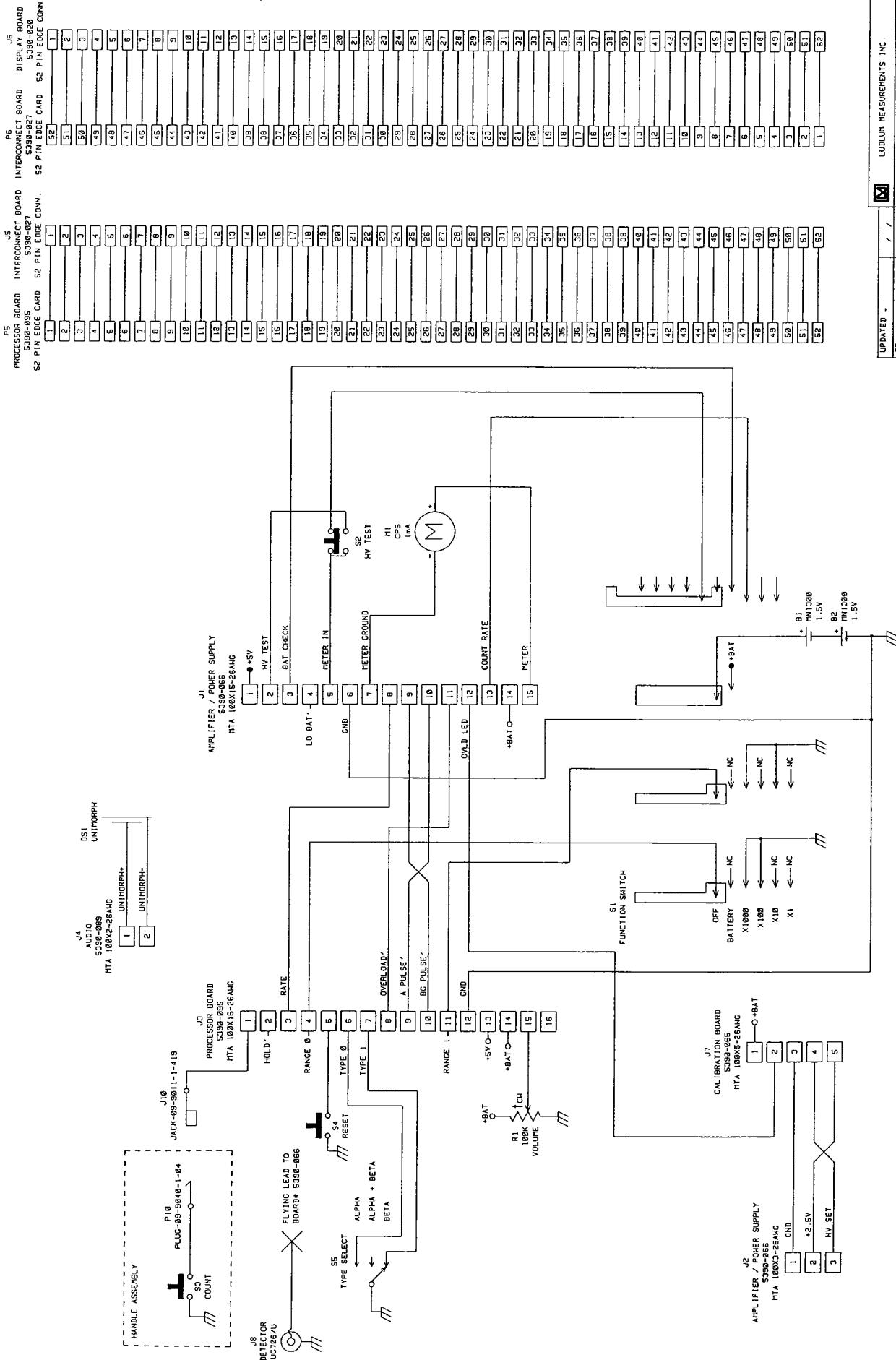


UPDATED	-	LUDLUM MEASUREMENTS INC.		
DR CKB	07/17/95	TITLE : DISPLAY INTERCONNECT BOARD		
TSER JCH	07/17/95	BOARD S139-117		
APPD RDS	16 Jun 95	SIZE	MODEL 2224/2224-1	SHEET 398
NEXT HIGHER ASSY		C		124
	[6-Jun-95 S139-117]			SHEET 1 OF

	LUMIN MEASUREMENTS INC., SHEETWATER, TX.
DR	SKB
CHK	07/17/95
APP	C-2 & 4
DESIGN	BOARD 5398-117
REV	07/17/95
COMPONENT	MODEL 2224
OUTLINE	FILENAME: 193J98117
	13:34:28
	1-Jun-95
	REVISION
	SERIES
	1
	125



REF	AUTHORITY	ZONE	LIR	DESCRIPTION	DATE APPROVED
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UPDATED -	/ /	LUDLUS MEASUREMENTS INC.
DR CLK#	05/19/94	TITLE : HIRING DIAGRAM
CRK RDS	2/2/94	DESIGN PH: 6A/21/93 BOARD: 380-988
APPD	J6 3	SERIES SHEET 1
NEXT HIGHER ASSY.	10293	J6 2224
-	-	J6 380
		SHEET 1 OF 1

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27-Dec-95

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